WAR FOOD ADMINISTRATION
Office of Distribution
Washington 25, D. C.

April 28, 1944

To: Lt. Colonel Ralph W. Olmstead

From: Karl Brandt
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Subject: Recommendations for Utilization of Surplus Potatoes by Steaming and Ensiling

I. The Economic Principle

The surplus of potatoes which the War Food Administration has to take off the market has the following commodity characteristics. The chief nutrient in the potato is starch, the content of which varies between 13% and 14% for the early and 17% and 22% for the late varieties, with intermediary contents for the intermediary types. Such content designates the material as a low-concentrate carbohydrate food or feed. Potatoes, early varieties particularly, are a perishable commodity which cannot stand storage under higher temperatures. Moist, hot weather is a condition which leads to complete deterioration within a few weeks, especially if the potatoes are stacked high, because pressure upon the lower layers will bruise the tender tissue and open the skin for bacteria. Even a staple height exceeding only three feet is dangerous to the sensitive early types when dug early in the season. Left in the ground for longer maturing improves their storage quality. When exposed to daylight, potatoes, which are living tubers, begin to develop a green color and to sprout. As a member of the family of poisonous nightshade plants, the tubers will develop in skin and sprout the poison solanin. This poison is concentrated enough to seriously affect most animals; only sheep can stand a considerable dose of it without becoming ill.

The outlets into food use for any sizeable surplus are exceedingly limited. Canning of potatoes is a wasteful process. The only process which permits converting potatoes into a durable and transportable staple is dehydration, but it pays only if the potato acreage is near to the dehydration plant. The dehydrated product has to compete with the fresh potato in the market. It can compete on an economic basis only if the raw material is purchased at considerably less than half the wholesale market value of fresh potatoes. Dehydrated potato flakes have a starch value of roughly 70% which is roughly the same as the feed value of barley, but about 12% less than the feed value of corn. Dehydrated potato flakes will not necessarily increase the human consumption of potatoes, but will essentially displace, in certain seasons, the consumption of fresh potatoes - and thereby only transfer the problem seasonally. This nexus has been amply demonstrated for many years in the German potato market where many efforts were made to increase the human consumption, but with little or no success. Even if school lunches and various forms of subsidized distribution of potato preparations should be used as additional outlets, it seems almost certain that the surplus of fresh potatoes which has to be taken out of the market by the government will not be substantially diminished.

There are methods of dehydrating chopped or crushed raw potatoes which suffer from the other shortcomings and therefore are ignored in this memorandum.

What remains is the utilization for industrial purposes and for feed. Among the industrial uses, two are outstanding; one, the distilling of alcohol and the other, the processing of starch. Both uses compare unfavorably with the similar utilization of corn and other grains since the only component that counts in both processes is starch - which is the same in the potato as in the grain. It is obvious that the potato must lose in any case. With its content of 70% to 80% water, the commodity has to carry a 4 to 6 times greater freight charge up to the processing factories. Only in cases where the factory stands in the immediate neighborhood of the potato fields is this handicap reduced to a minimum.

In the case of alcohol as well as starch manufacture, only a part of the starch can be recovered. What remains as a by-product of distillation is the slops which again has to be utilized by animals, preferably cattle. In the case of starch manufacture, potato pulp is left, which can either be dehydrated and then shipped to feeders or has to be fed on the spot, probably to ruminants. The relatively best use is, therefore, the one for feed purposes.

Potatoes can be fed in the following forms: (1) raw; (2) steamed; (3) raw silage and (4) steamed silage. All these forms of feeding require a washing or rinsing process. Any substantial amount of sand or soil getting into the intestinal tract of animals reduces the digestibility of the nutrients and, if excessive, it causes serious intestinal trouble. Admixtures of sand also deteriorate the teeth of cattle. Hogs are the least sensitive to dirt. As figures presented later will indicate, dairy cows and sheep are the only animals which will digest and utilize raw potatoes fairly well. Dairy cows and sheep in lactation respond with good milk yields to the feeding of raw potatoes. Horses and poultry, as well as cattle and sheep, when fed for meat production and in process of fattening, utilize the starch content successfully only when the potatoes have been steamed.

The steaming process changes the physical qualities of the starch enclosed in cells. It breaks the fibrous cell walls, leads to the gelatinization of starch and gives all starch crystals a greater surface, thereby rendering them more accessible to the attack of gastric juices - so that nearly full utilization is obtained. Moreover, after steaming the crystallized starch absorbs all the free moisture enclosed in the cells so that the steamed product has the consistency of a thick paste without any free liquid.

While the two forms of feeding mentioned so far, i.e., feeding raw and feeding steamed, utilize the substances of the potato without essentially changing the chemical composition, the other two methods apply a fermentation process in order to convert a perishable into a stable commodity. The tubers in raw as well as in steamed condition are useful as feed only so long as no wild bacteria cultures spoil them. Fermentation, which yields sweet silage, depends upon lactic acid bacteria. Due to the starch content, lactic acid fermentation will develop freely and without any additional culture in crushed raw as well as steamed mashed potatoes.

In fact, the spontaneous development of lactic acid bacteria is so strong that crushed or steamed potatoes can be used to guarantee a good silage process in highly acid succulent materials such as grass or beet leaves. The only condition required for assuring lactic acid fermentation is the absence of large air pockets in the silage and also the protection against entrance of water from the outside into the silage.

Silage made from raw potatoes suffers from the same limitation to its use as the raw potatoes. For this reason it has never been adopted on any large scale in Germany. When the development of potato silage was still in the initial stage, the use of raw potatoes was tried by experiment stations as well as by many pioneering farmers.

Unquestionably the best method remains, therefore, the steaming and ensiling of potatoes. Steamed silage is readily accepted by any sort of animal. Cattle and hogs find it so palatable that they take to it without any preliminary admixture of other feed. Steamed potato silage lasts for long periods and can, if protected from damaging outside effects, be carried over from one crop year into a third year. Losses of nutrients stay within limits of about 10% over the whole period of storage in pits.

In Germany, a country which grows an equivalent of approximately 10 million tons of grain in the form of potatoes, this whole matter was an issue of great importance for the entire livestock and feed policy. It was therefore investigated thoroughly in the year 1927 by the German Economic Inquiry Commission. At that time, the Commission held many hearings attended by the best experts in the country including the greatest authorities on animal nutrition and animal husbandry. In Volumes No. 5 and No. 6 published by the Commission (both of which are at hand in the USDA library) the pertinent data of the experiments conducted by the internationally known authorities, Hansen and Voltz, are presented. Voltz's data show the following utilization of different preparations of potatoes by milking dairy cows.

Type of Preparation	Milk Yield per 100 kilos of potatoes	Butter Fat
Potatoes, raw (whole)	27.7 kg	1222 grams
Potatoes, steam silage	22.6 "	1191 "
Potatoes, raw silage (crushed)	14.97 "	1168 "
Potatoes, steamed	1.66 "	694 "

This table indicates that the steamed potatoes yielded next to no milk for the very reason that the cows utilized all the gelatinized starch in forming meat and bodyfat while the same potatoes fed raw yielded well as milk feed and steamed silage yielded next best. Another result of experiments conducted by Voltz, as incorporated in the report by the Inquiry Commission, refers to the utilization of steamed potatoes by different animals.

Type of Animal	Percent of organic substance digested	Percent of crude protein digested
Hogs	96	77
Ruminants	84	51
Horses	93	88
Chickens	78	47

These experiment data show that hogs and horses are the best utilizers of potatoes, the ruminants follow, and chickens are the least able to digest the starch.

For efficient feed use of potatoes, it is important to know, aside from this differential ability of various animals to digest potatoes, the limits that can be fed to an animal. About this question such an enormous amount of experimentation has been accumulated in Germany that the repetition of experiments on a large scale in this country seems avoidable.

Horses can, as a rule which is also quoted in the Inquiry Commission report states, "be fed with 15 kilos (33 pounds) of steamed potatoes or 10 kilos (22 pounds) of steamed potato silage per day per 500 kilos (1100 pounds) live weight." (Voltz). The difference between this ration and the carbohydrate requirement should be made up by grain and hay but the horses do not need any additional protein because they have a very low protein requirement. They need however, according to German experiments, 50 grams per day of a mixture of calcium carbonate, calcium phosphate and salt for better digestion. Horses can be kept in an excellent weight condition although it is found that for hard field work they will sweat more profusely than if fed with grain only. Old horses for slaughter can be finished with potatoes to a better carcass yield of meat.

Beef cattle can be fed with 30 to 35 kilos of potatoes per head per day for fattening, provided that sufficient roughage and protein are added. The best return from feeding potatoes to cattle is obtained by fattening older cattle which have already built the bone frame for the very simple reason that it takes less protein per unit of potatoes than if young cattle are fed. The protein however is more expensive than the potatoes.

The following formula is for grown up meat cattle for the feeding pen.

	Beginning of Fattening			During Fattening			End of Fattening		
	kg	Protein	Starch Equivalent	kg	Protein	Starch Equivalent	kg	Protein	Starch Equivalent
Hay	4.0	0.20	1.45	4.0	0.20	1.45	4.0	0.20	1.45
Potatoes	25.0	0.22	4.95	25.0	0.22	4.95	20.0	0.18	3.96
Cracked grain	1.0	0.07	0.66	1.5	0.10	0.99	2.5	0.17	1.65
Oil meal	0.5	0.19	0.37	0.5	0.19	0.37	0.5	0.19	0.74
Total	--	0.68	7.43	--	0.71	7.76	--	0.74	7.80

This formula shows that toward the end of the fattening period the amount of potatoes has been reduced but the amount of the cracked grain in the ration is increased, for the simple reason that the voracity has been kept up by that change, while at the same time, the quality of the meat is improved, getting better "marble" texture.

The best German authority on the economics of animal husbandry, and still today the leading specialist in his field, Dr. W. Woermann, in his book on "Forms of Management and Profitability of Animal Husbandry," Berlin, 1933,[1/] gives a table (page 82) which elaborates on the relation between the profit derived from feeding potatoes to cattle and the price of oil cake on the one hand and the price of fat cattle on the other. Obviously the profitability of feeding potatoes must increase with the reduction in the price of oil cake as well as the increase in the price of fat cattle. From this, it results also that the lower the price of protein in relation to the price of potatoes, the more profitable becomes the feeding of potatoes also to younger feeder cattle.

Pigs. The famous authority on pig feeding, Dr. Lehman of the University of Gottingen, established the most profitable ratio as follows: 450 kilos potatoes plus 59 kilos cracked grain plus 23 kilos fish meal or tankage. (Inquiry Commission, Volume 5, page 54.)

One of us[2/] has used over many years of feeding practice on a large scale on German farms the following ration (expressed in American pounds): roughly 1200 pounds of steamed potato silage plus 150 pounds of cracked grain plus 50 pounds fish meal for the production of 100 pounds live weight of hogs. Pigs fed between 5.5 and 16.5 pounds of steamed potatoes per day plus grain and fish meal made net gains in live weight of between 1.5 and 2 pounds a day.

According to the German experiments of many years, it can be said that the fattening of hogs and the fattening of meat cattle are the most profitable uses of potato silage. We quote Hansen's statement of 1927 before the German Inquiry Commission: "Ensiling of potatoes for hog feeding, if handled properly, can be recommended unconditionally and its general introduction can be urgently advocated." In the same report it was also stated that compared with dehydration, ensiling has the advantage that it is less expensive and can be handled without the installation of special machinery. The report went on: "It (ensiling) cannot replace dehydration because it can only equalize the feed supply on the producer's farm throughout the year and therfore must not be expanded beyond the stock on the farm. Dehydration, on the other hand, has the task of equalizing the annual potato crop fluctuation and equalizing the regional differences between surplus and deficit areas. For this reason, ensiling has the same importance in all parts of the country while dehydration must remain confined to the potato surplus areas of the East (Germany) only."

1/ E. Woermann, DIEVEREDLUNGS 'IRTSCHAFT, Berlin 1933

2/ J. Kraemer

It is interesting to see that after this strong recommendation before the German Inquiry Commission, the German government introduced in the following decade, by means of subsidy, literally tens of thousands of concrete silo pits exclusively for steamed potato silage on farms. Thereby it succeeded in stabilizing the feed supply on the farms throughout the year as well as from one good crop year to a bad one.

It is obvious that due to the low concentration of the starch in potatoes compared with grain, the profitability of feeding steamed potatoes must increase at the same rate as unnecessary moving of this bulky material is avoided. The principle must be to move the meat animals to the potatoes - not the reverse - and, if possible to have the silage stored on or close to the potato growing acreage, for the very simple reason that it is much less costly to move cattle or pigs over longer distances into feeder lots than to move the bulky mass of potatoes. Moreover, the steamed potatoes are bound to lose over longer periods of pit storage up to 10% all wastage told, provided that they are not moved unnecessarily over any distance from the pit into the animals.

We are of the opinion that in the United States the same experience will be met as in Germany, namely, that by introducing the more or less permanent starch of potatoes as silage within the potato growing districts, the livestock production in those areas will be balanced and better stabilized, while at the same time, the steaming on the farm will put the absolute floor under the prices for potatoes - which means that the conversion of potatoes into pork or beef, carried on in the most efficient way, will determine that particular floor. The importance of this method will be greatest wherever the local supply of feed for cattle or hogs fluctuates most under the impact of rainfall.

If the technique of storing potato silage in pits can be worked out successfully, it may very prove that this method introduced under the war emergency will prove to be as permanent a benefit to the potato growing areas as the widespread use of this method in Germany which also developed from an emergency situation.

II. The Risk of Failure

So far as we can see the only serious point of danger for the whole project lies in the possibility that the fermentation process may be upset or prolonged unduly by conditions of too high temperatures. It must be stressed that the overwhelming evidence of German experience is all based on the temperature prevailing in the very temperate climate of Germany where prolonged periods of excessive heat are unknown.

This question of applied bacteriology ought to be explored with fermentation experts.

It is our assumption that great depth of pits as well as enlarged coverage of the silage from the top should be the means to minimize deleterious effects of high outside temperatures.

The high summer precipitation in Southern States makes special precaution against penetration of rainwater into the pits advisable.

III. The Recommended Procedure for Steamed Potato Silage on a Large Scale

Wherever a concentrated potato acreage of thousands of acres yields a surplus and where the ground water conditions are such that the laying out of pits for silage does not run into costly obstacles, it seems advisable to use the following arrangement which is built around the idea of minimizing the transportation costs:

Directly on the potato acreage, or closely adjacent to it, a stretch of temporary railroad track should be laid out in improvised fashion in order to establish on the one side of the track the pit for the steamed potatoes, and on the other, the feeder lot for the cattle to be fed with the potato silage. The pit should be dug with a bulldozer. As further equipment, one should try to rent from one of the railroad companies servicing the area, the necessary number of coal or sugar beet gondolas, which permit automatic unloading from the bottom, and a switch engine for moving the cars on the tracks as well as for supplying the necessary amount of steam.

It is suggested that on the feeder lot side of the tracks, a wooden ramp should be constructed so that the dump trucks can run from the potato fields up the ramp, back up, and unload by hydraulic liftpower into the gondolas. This equipment should permit continuous operations, if need be, day and night.

The gondolas have to be equipped with canvass-covered, wooden lids on hinges and with two steam pipes at their bottom which require outside of the cars couplings for steam hose running from one car to the next and for connection with the engine.

The potatoes have to be washed somewhere on the way from the field to the gondolas. The easiest way of doing it is heavy rinsing from the top with a hose directly in the gondolas before the lid is closed. This will do if little dirt clings to the tubers, but it may be necessary to avoid the washing in the cars in which they have to be steamed because it is difficult to remove the dirt from the bottom of the cars. It may occur also that if too much dirt is washed off the potatoes, it will clog up the steam pipe. One handy arrangement for washing may be a big vat into which the potatoes can be dumped from the trucks and out of which they are lifted into the gondolas by an endless snail elevator. In that case, one does not need the ramp, but instead the big wooden vat and the elevator.

Once a gondola is filled with washed potatoes and the lid is closed, the steam has to be introduced for a period of thirty to forty minutes. The time required depends to some extent on the pressure and the heat of the steam. The condensing water accumulating at the bottom must be permitted to drain from the gondolas. While one gondola is under steam the next one should be loading, or if one wants to multiply, one could load three at a time, steam three and have another three in the loading process, using a set of 9 cars.

The next step is to dump the steamed potatoes into the pit dug along the tracks. The pit has to be filled to the top; therfore, one has to proceed gradually with the dumping toward the other end of the pit. The steamed potatoes require from one to three days to cool off. After that they should be covered with chaff, chopped straw or hay as a protective cover - on top of which is finally placed a layer of four or five inches of soil. The top of the silage should be shaped as a saddle roof to let rainwater flow off safely. Once the pit is filled, one is at liberty to decide when it should be used. As long as no water can seep into the pit and it is protected against damage by man or animal, which can be done by a fence or barbed wire, it is protected against spoilage until the time of feeding. According to experience, it takes about six weeks until the fermentation has penetrated to the bottom of the silage and is in proper condition to be fed. Before that time, it is not advisable to feed the silage as it is not yet "well done." As in the case of slightly souring milk, silage in this unfinished condition may upset the digestion of the animals.

The pit should have sharply slanting sides. If it is dug into clay or loam soil, the walls should stand easily by the texture of the soil. The walls may be fortified by spraying a tar oil over them. In sandy soils or muck soils, it will be necessary to put a wooden lining on the floor as well as the walls, which naturally adds to the costs, but prevents excessive waste. On heavy soils, the problem of drainage is more important. A location must be found which prohibits the collection of rainwater in or around the pit. The pit itself can be dug with the least of costs with a bulldozer or a dragline and should, for the sake of drainage, be provided with a small channel at the bottom which has to be covered by boards. This drainage is also necessary for preventing flooding by rainwater when the pit is partly empty. Otherwise, there are no requirements for digging the pit or trench except that its width should not exceed the convenience of filling and emptying. Much care should be used in choosing the best shape of the layout of the pit as well as conditioning the edge. If much admixture of dirt to the silage in the process of emptying is to be avoided, it is necessary to have clean edges. It may be advisable to edge the pit with boards. The floor of the pit should be absolutely level so that water which may seep out of the silage does not accumulate in spots. If the pit were 4 yards wide at the bottom and 5 yards wide at the top and filled up to the depth of two yards, every running yard would contain roughly twenty tons of raw potato equivalent. In other words, if the pit were not deeper or wider, 1000 tons of potatoes in steamed form would take 50 running yards of the pit. This requires that when it comes to much larger quantities, it will be necessary to use much deeper and wider pits. The difficulty with such pits will lie in the more bothersome emptying into the gondolas. Great depth is an advantage for the preservation of the silage. Therefore, if the soil conditions (ground-water table) and the location otherwise permit, it is advisable to dig the pits deeper and wider. This, however, has to be determined by local conditions.

After the pit is filled with the potatoes and the steaming operations over, the entire equipment, with the exception of one gondola car, can be returned to the railroad company. The remaining gondola will be very useful for purposes of unloading and conveying the silage into the feed manger.

While the whole procedure has to be worked out locally, it seems feasible to use a small conveyer belt with metal cups attached which, after removal of the soil and straw covering, will lift the silage from the pit into the gondola. The loaded gondola-car can be moved on the tracks with the use of a tractor. By that time a wooden feed trough would have been built with a fence next to the track so that from the gondola car, the silage can be dumped straight into the feed trough and distributed over the whole length of the trough. The cracked grain that has to be fed with the potato silage has to be spread on top of the silage and will probably be thrown in there from a truck. Later on, in order to segregate the animals which enter the last stage of fattening as well as the ones that are the best converters, it is easily possible to fence off a part of the feed through and add more cracked grain to the ration to prepare them for the finishing as suggested in the table by Woermann. It should be possible to take care of up to a thousand steers by two to three men.

IV. Alternative Procedure with More Decentralization and on a Smaller Scale

Wherever the method described in No. III is impractical because of the scattered locations of potato fields or the necessity to store in smaller amounts on a variety of farms, the problem has to be solved in a different way. Then, the real difficulty consists of making steam available at low costs. The difficulty in establishing the pits in proximity to the feeder lot shrinks as the amounts of potatoes to be stored gets smaller. Moreover it is possible to use existing silos for filling with steamed potatoes. Ordinary big wooden water tanks present also a good and useful type of container for potato silage, wherever they are available.

The question is then what sort of equipment to use for getting the potatoes washed and steamed. One feasible makeshift solution lies in the use of wooden box wagons or box trucks which have to be supplied with a wooden lid. The introduction of steam pipes, which have only to have the length of the wagon, does not present any difficulty. But the steam has to be taken from a steam boiler. If there is a heavy stationary steam boiler available, as is frequently the case with creameries or sawmills, these wagons or trucks can be moved close to them and be connected by a steam hose. It again takes thirty to forty minutes to get the potatoes steamed. After that they have to be dumped into whatever pit or silo is available. If no such stationary steam source in which it becomes necessary to make a mobile steam boiler is available, any good machine shop will be able to fit a steam boiler on top of a two-wheel trailer which can be hitched to a heavy truck. The truck could carry coal needed for heating as well as the steam hose and the couplings.

The more decentralized the storage pits are, the more mobile steam boilers will be necessary since it takes considerable time to get a large volume of potatoes steamed. The washing in this procedure had best be done in the box wagons or trucks with water hose by rinsing the full load before steaming.

V. Alternative Community Silage Plan

If it should be found impossible to rig up enough steam units to get the potatoes steamed in time for individual farmers or feeders, it may be a good compromise to haul the surplus potatoes with trucks to one or two central places in the county where a stationary steam boiler can be put up and a number of large pits dug. This would require not only the moving of the potatoes from the fields up to this place, but also the moving of the cattle to the feeder lot adjacent to the pits. This seems not impossible.

Cattle of certain age and weight classes could be put together in the feeder lots and the feeder costs could be distributed at the end of the fattening period according to a key which uses the net gain in live weight.

VI. Necessity of Diversion to Different Forms of Feeding

In order to prevent excessive congestion in the surplus disposal, other means should be used in combination with steam silage. First of all, the digging should be delayed because potatoes keep better in the ground than when piled up high after digging. After digging as much of the surplus as possible should be sold to dairy farmers and sheep farmers for feeding raw. A preferential price and publicity for this method should move a considerable amount. Beyond that farmers should be urged to start steaming and feeding potatoes.

VIII. The Price and the Method of Sale of Silage

The only fair method for defining the price of the silage to be charged to livestock feeders is by setting it slightly below the equivalents of the corn price at the same location. The starch content which is easily tested by the agricultural experiment stations, is the determining factor. In other words, the silage should be sold on the base of cents per bushel of corn feed value. This would mean that silage is offered at $1.40 corn price for the equivalent weight of silage. How much weight this will be depends exclusively on the starch content of the silage. With early potatoes farmers would receive say 300 - 350 lbs. of silage for $1.40 equivalent to one bushel of corn. For late potatoes they might get only 300 lbs. of silage.

For advertising, it is suggested that the silage is offered as follows:

"Corn available at $1.40 per bushel to cattle and pig feeders in the form of potato silage."